

Towards Sustainable Production and Consumption:

Preparedness for Product Service System Concept

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1. Introduction

Eco-efficiency strategies and policies, which have resulted in environmental gains that translate into increased resource efficiency and lower levels of emissions, in particular CO₂ emissions along the life cycle of products and services, might be offset by rising levels of consumption on the demand side. Hence, both sides of the coin i.e. the system of production and consumption systems need to be assessed if more sustainable patterns are to be achieved.

Establishing sustainable production and consumption systems can be possible via functional thinking practices. Functional thinking takes the focus from provision of resource intensive product to satisfaction of needs and wants through service systems, where material products are treated as capital assets rather than consumables. An application of functional thinking is the Product Service System (PSS) concept. Providers of PSS applications aim to generate profit not from selling as many material products as possible, but from providing a function of the product or service. Potential environmental benefits of PSS applications stemming from decreased use of virgin materials in production and lessened resource consumption at the use phase are being recognized. Applications of PSS can be seen in many sectors such as Information and Communication Technology (ICT), energy, transportation, food and in many forms such as remanufacturing, demand side management, chemical management services, car sharing schemes, functional designs, etc.

However, supply and use of such applications might need considerable assessment of business practices and consumer behaviour. For business, designing and implementing PSS applications might require a new set of internal conditions such as shifting the business vision and adjusting the corporate culture to provision of functions. On the other hand, understanding of individual and social factors guiding the consumers' acceptance of PSS applications is required.

This paper is an extract from a study, which is conducted with the aim of provision of a direction enhancing business ability to offer new or improved PSS applications with increased consumer acceptance and in turn enhanced resource efficiency.

Applications in the Information and Communications Technology (ICT) sector are chosen as the focus of the paper. Although it is debated that this fast developing sector can potentially contribute to dematerialisation of systems, limitations within the sector still remain unclear.

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Here, it is aimed to suggest an overview of the aspects for business preparedness and consumer acceptance of PSS applications providing particular functions in the ICT sector. The focus is on the company level dynamics, despite it is recognized that factors of macro level preparedness such as infrastructure availability, economic and social conditions, public support, etc. are essential to consider for system preparedness.

1.1 Structure of the paper

This paper consists of four major parts. Firstly, the concept of Sustainable Production and Consumption and the problem with realizing this concept is defined. Suggesting functional thinking as one of the solution routes, the role of Product Service System concept in achieving such a vision is proposed.

In the second stage, examples from the ICT sector, which are collected through primary and secondary literature search and research results on the ICT sector environmental impacts, provided a source for quantifying PSS applications and formulating strategies. These strategies are then grouped according to the “Material Input per Unit of Services” concept in order to provide a direction in realizing the PSS concept. However, a comprehensive set cannot be gathered, since detailed case studies on PSS concept are currently not available.

In the third stage, the method of concept specification² is used to derive major factors and their sub-factors for business preparedness and consumer acceptance. This method has been developed by social sciences and is used here to break down an issue into its aspects. On the business side, the research question; *“Which factors have to be in place in a company to be able to develop and implement functional thinking (or PSS concept)?”* is tried to be answered. To determine a company’s readiness, the collected examples are analysed in terms of the foreseen managerial factors that are in place supporting these PSS applications. Firstly, major category of factors is identified and then these are divided into sub-categories.

On the consumer side, the research question; *“Which factors have to be considered in the name of consumers for them to be involved with PSS applications?”* is tried to be answered. Consumer acceptance factors are derived through analysis of consumer behaviour attributes. In this study, attributes readily available in the field of consumer behaviour are scanned to find the relevant ones for consumers to take on the collected set of examples. Lack of detailed case studies remains as a limitation faced also at this stage of the study. At the fourth stage of the study, a systematic to merge the both sides of the model is devised.

² Diekmann (1998). Empirische Sozialforschung. Grundlagen, Methoden, Anwendungen [Empirical Social Sciences. Basics, Methods, Applications]. 4th edition. Hamburg. Germany. p. 181; Schnell, R./Hill, P.B./Esser, E. (1995). Methoden der empirischen Sozialforschung [Methods for empirical social sciences], 5th edition. München/Wien/Oldenburg. Germany, p. 118; Köhler, R. (1987). Informationen für die strategische Planung von Produktinnovationen [Information for strategic planning of product innovations]. in: Klein-Blenkers, F. (Ed.). Distributionspolitik [Distribution politics]. Cologne, p. 85; Hujer, R./Knepel, H. (1984). Inhaltliche und formale Kriterien der Analyse ökonomischer Systeme [Content-related and formal criteria for the analysis of economic systems]. in: Roth, E. (Ed.). Sozialwissenschaftliche Methoden [Methods for social sciences]. München. Germany, p. 619.

2. Sustainable Production and Consumption Systems and the Role of Product Service Systems

2.1 Defining Sustainable Production and Consumption Systems & Understanding the Concept of Product Service System

It is clear that decrease in unit resource use can easily be neutralised, if the total amount of resource use rises. For example, at the macro level, the evidence shows that the total material requirement in Japan, Germany and the United States rose by an average of 27.7% over the past 20 years, even in the face of the efficiency gains (Adriaanse, et. al., 1997, p.12). In this sense, the problem of prevention of losses from the natural capital deserves a different perspective. The efforts have to be directed to tackle the problem of achieving the highest possible wealth with the lowest possible input of natural resources.

Since Agenda 21, the issue of unsustainable consumption (SC) have been addressed through a series of meetings, dialogues, research and publications from the UN Commission on Sustainable Development (CSD), United Nations Environment Programme (UNEP), Organisation for Economic Cooperation and Development (OECD), United Nations Development Programme (UNDP) and other business, consumer and research organisations. Though early definitions did not indicate the problem of changing the potentially unsustainable aspects of human activity, later expansions included the phase of selecting and purchasing the product or service, because of the indirect impact of product choice through its influence on producers' decisions (UNEP, 1999). There is now a wide consensus that SC is not limited to the consumers' use of services and product, but rather entails the indirect effects through the purchasing decision (OECD, 2002).

Here, **sustainable production and consumption** is defined as a **vision** of achievement of equal quality of life through provision of goods and services, which satisfy basic human needs and desires without depleting absolute amount of natural resources and increasing waste outputs. By this, it is aimed to reach an equally distributed quality of life for the present generations without compromising the ability of future generations to meet their own needs. The inequalities in consumption between countries and within countries are also recognized by this definition, as this constitutes a major distortion in progress towards sustainable development. For example, the overall consumption of the richest fifth of the world's population is 16 times of the poorest fifth (UNEP and CDG, 2001, p.9).

Establishing a sustainable production and consumption system requires a systems thinking approach. Such approaches addressing both sides of the coin are quite rare in traditional economies. In this respect, functional economy could be brought forward. Functional economy recognises the value of utilisation as a performance driven orientation where the consumer pays for the utilisation of the product (Dalhammar et al., 2002, p. 19). In a functional economy, products are considered as capital assets rather than consumables and closed loop systems are aimed in order to keep the material flows constant. To reach such systems, a network of actors is aimed, instead of having detached companies.

The Concept of Product Service Systems

Within the scope of a functional economy, the concept of Product Service System (PSS) is a candidate to supply systems solutions to fulfil consumer needs as efficiently as possible from both economic and environmental point of view. PSS supports the closed loop aspect of functional economy with the goal of reducing life-cycle environmental impacts, which also addresses the phases of consumer involvement.

The concept of product service systems is based on the assumption that customers actually need the function provided by a product but not the product per se. The provider of PSS, in this respect, optimises the use (or function) of goods and services and thus the management of existing wealth (goods, knowledge and nature) where the consumer pays only for the utilisation of the product. This leads to the situation in which the traditional demarcation line between manufactured goods and services is becoming obsolete (Schmidt-Bleek, 1999).

In this paper, **product service system** is defined as a **concept** aiming to establish a **network system** of economic and social actors including the consumers, which can be sustained with a physical infrastructure, **delivering a function** requested by the consumer **at a lower environmental impact level** than the one that would be created by the assembly of discrete production chains to fulfil the same function. In the light of such a vision, major aspects foreseen for PSS are systems thinking, closed loop systems, multi-actor learning networks, consumer focus, cost minimisation per function provided and achievement of resource efficiency.

2.2 Understanding the Environmental Impact of PSS in General & in the ICT Sector

At the application level, even though one cannot still observe cases reflecting the complete vision of PSS concept, the currently happening shift towards service economy³ is believed to have the potential to reach it. For this reason, recent PSS applications are rather sought in the services sector or service providing companies in relation to a material product. Similarly, PSS classifications usually refer to the material intensity of services (Hockert, 1999, p. 98-101; Manzini et al., 2001; White et al., 1999, p.16) or the concept of “servicizing”⁴ (White et al., 1999, p.10).

Such categorisations of PSS can well be matched with the concept of Material Intensity per Service Unit (MIPS) (Schmidt-Bleek, 1993), which might be used as a tool or indicator to facilitate eco-efficiency improvements in the design process. As a rule: the larger the value of MIPS, the higher the “ecological price per unit service”. MIPS is also known as the “ecological rucksack” and facilitates the measurement and comparison of consumption of resources involved in products, product lines, processes, services and economic areas throughout their life cycles.

The proposed link between the MIPS concept and the strategies for PSS applications might lead to three basic strategy levels:

Type I – Supply-chain Optimisation Level: decreasing the Material Intensity (MI) of a service unit from cradle to grave. At this level, consumers own the product and producers are usually responsible for the end-of-life implication of the product.

Type II – Network-wide Optimisation Level: increasing the Service Intensity (SI) of a certain amount of material flow. At this level, producers own the product.

Type III – System Optimisation Level: decreasing the material flow and increasing the service intensity. At this level, the service unit changes with the aim of providing as dematerialised service as possible. (See Appendix Table 1 for a list of corresponding strategies derived from ICT sector applications).

Here, each level matches with a strategy directed to make a change either in the denominator or the nominator or both of sides of the MIPS ratio. Type I is found to be

³ In fact, as previously discussed, service economy is steadily stretching its boundaries to creation of a functional economy. This growth can be observed with the change of the sale of the product to the sale of function or utility. However, to emphasize the current focus on services in search for PSS applications, the term “service economy” is used here.

⁴ Servicizing is defined by White et al. (1999) as the emergence of product-based services which blur the traditional distinction between manufacturing and traditional service sector enterprises.

directed to change the “Material Intensity (MI)”, while Type II is directed towards changing the “Service (S)” and on the other hand, Type III aims to change both sides of the ratio.

The link between the MIPS concept and the PSS design strategies can also be shown on the “Service Units” versus “ecological rucksack value” graph. An existing service unit (the black dot on the black curve) can be improved in three different ways, where Type I improvements bring a shift in the resource flows of the service unit, while Type II improvements introduces a move along the curve with similar material flows but increased service use and finally Type II improvements may provide both a shift of the MI curve and move along this curve. (See Figure 1)

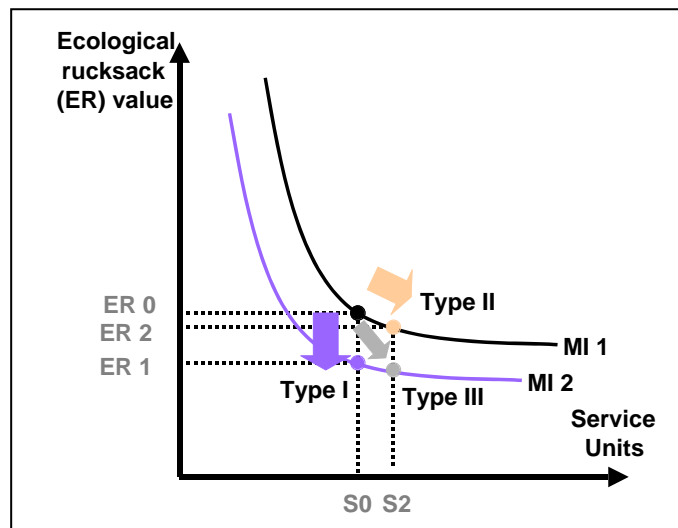


Figure 1–Illustration of Type I, Type II and Type III PSS strategies – Service Units vs. Ecological rucksack Graph.

Understanding the Environmental Impacts of ICT Sector Applications of PSS

It is currently debated that ICT sector can intrinsically contribute to reduction of material intensity as the resource intensity of ICT infrastructure is relatively low and ICT applications can enhance efficiency of logistic structures (Heiskanen, 2000). This sector might possess huge potential for the shift towards a service economy; however, the main problem stays as finding less resource intense routes of its contribution.

PSS applications in the ICT sector might be found in all three different types of PSS applications. For example, design of printers consuming less energy at the use phase, take-back services for mobile phones correspond to Type I applications; while modular design of LaserJet printers, multi-functional DVD players, leasing of photocopiers correspond to Type II examples. On the other hand, service substitution such as e-commerce services, mobility services, video-conferencing and set up of integrated systems to control performance of home appliances can be included in Type III (Further PSS application examples can be found in Appendix, Box 1).

One might assume that e-commerce as a Type III application of PSS, would have considerable potential for resource reduction. Specifically, as far as information-based e-commerce⁵ (such as online delivery of music) considered, there can be potential. In this

⁵ E-commerce activities can be divided into two major categories depending on the degree of physical material used to provide the service associated to the transaction object; “information based e-commerce” and “product-based e-commerce”. **Product based e-commerce** is depended on a physical product for the

respect, the product as well as parts of the infrastructure such as space for retailing or transportation to the retailer becomes obsolete. However, the overall resource intensity of the build-up and use of ICT infrastructure or devices can still be considered to be quite energy intensive.

Testing the above assumption, in a recent study on environmental impacts of the ICT sector, the amount of resource use in three different forms of digital music provision i.e. purchase at a physical retail store, on-line purchase of CDs and on-line download of digital music, are calculated. It was found that the digital music distribution is 50% as resource intense as the other cases (Kuhndt et al., 2002, p. 40-47). This finding illustrates that PSS applications can enhance the resource efficiency per service unit provided significantly.

On the other hand, when the amount of resource use by each actor of the supply chain (i.e. from product/provision via retail to consumption/usage) at three different cases is analysed, a shift in the contribution of total material intensity (TMI) towards downstream was observed. In the case of digital distribution of music, for example, consumers contribute almost 90% of the TMI (See Figure 2). This means that consumers would require more energy and material (such as computers and CDs to burn) to extract the actual function from the system. (Kuhndt et al., 2002, p. 47) Here, it can be deduced that consumers' actions gain significance in PSS applications.

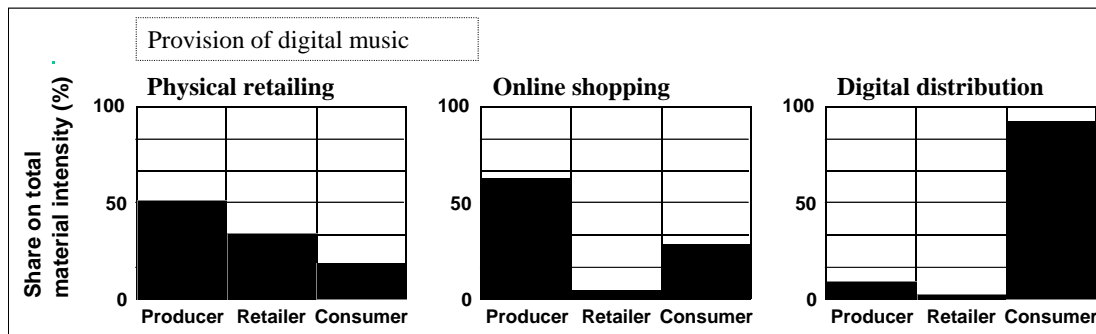


Figure 2 – Resource consumption in the life-cycle of information based e-commerce (Source: Kuhndt et al., 2002, p. 47)

Consequently, in response to the assumption given above, this study underlines that factors of consumer behaviour and issues of ICT infrastructure have to be carefully considered in order to design resource effective PSS applications. The designers of the PSS could be then advised, firstly to consider the environmental impacts along the life cycle and secondly, assess the acceptance by the consumers for the utilisation of the function (such as whether the desired function is the availability of music at varied times or provision of music at as single point in time). Otherwise, complete potential of resource reduction of PSS applications would not be utilised leaving consumers out of the system.

In this respect, during the design of the product service system applications, besides the total impact level of PSS application, what function consumers actually require, has to be assessed. Provision of the right function is essential for the full acceptance of the PSS applications; otherwise an increase in resource efficiency cannot be expected.

delivery of the product to the consumer such as the online purchase of CDs, whilst **information based e-commerce** refers to services that are delivered to the customer via an ICT infrastructure such as online banking and online music downloads or radio services (Kuhndt et al., 2002, p. 41).

3. Matching Consumer Acceptance & Business Preparedness for Product Service System Applications

In response to the findings from an analysis of PSS applications in the ICT sector, it is called for a systems approach i.e. contribution from all actors of the production and consumption systems.

A prerequisite for business to establish an effective product service system application is to be qualified for functional thinking. Therefore, firstly a self-assessment of business for functional thinking is proposed. As a part of this systems approach, secondly, a non-comprehensive list of factors derived from the limited collection of ICT sector examples, which can enable business to assess consumer acceptance of PSS applications are suggested.

This approach allows companies to take on qualification for functional thinking processes in consultation with relevant stakeholders (See Figure 3). At the same time, with the help of the opinion leaders, business can understand the factors for consumer acceptance and include them in the idea generation for PSS applications. Opinion leaders such as PSS experts, supply chain partners, environmental experts, consumer associations and public institutions are the possible stakeholders to be involved in the process. These experts would be able to provide business with mechanisms required for functional thinking and choose the level of PSS application in close corporation with consumers.

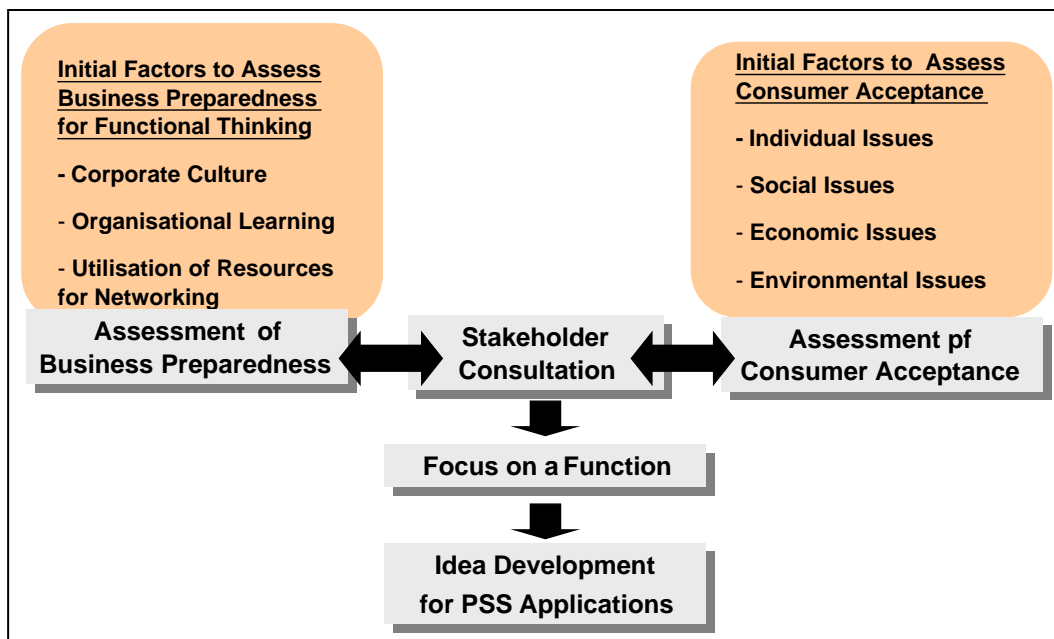


Figure 3– A process suggested to prepare business for functional thinking and understand factors for consumer acceptance.

Even though the decision on which stakeholders business can involve and how the consultation process can be run is a difficult one, the environmental and business side benefits of such a process is believed to be multiple. First of all, stakeholder consultation would support a life cycle approach, which would inform business on the interaction of actors among themselves and to the consumers. Secondly, learning from the members of the society on the environmental implications would be stimulated. Building learning systems is anyhow observed to be a prerequisite for business preparedness for functional thinking. Thirdly, business would be informed on the aspects of PSS and innovation opportunities, which would deliver competitive advantage.

3.1 Business preparedness for Functional Thinking

As discussed above, development and management of PSS applications, first of all, require set up of a vision towards functional thinking. Companies willing to employ one of the PSS application strategies shall be equipped with certain organisational factors before putting the foreseen strategy into action.

As mentioned in Section 1.1., through concept specification analysis (See figure 4) and taking the sector examples as benchmarks, three main categories are distinguished. These categories are then divided into aspects by consulting to primary and secondary literature sources and organisational practices found in the sector examples. Further deduction of indicators from these aspects would be carried out in the following stages of this study, while in this paper this part is not discussed.

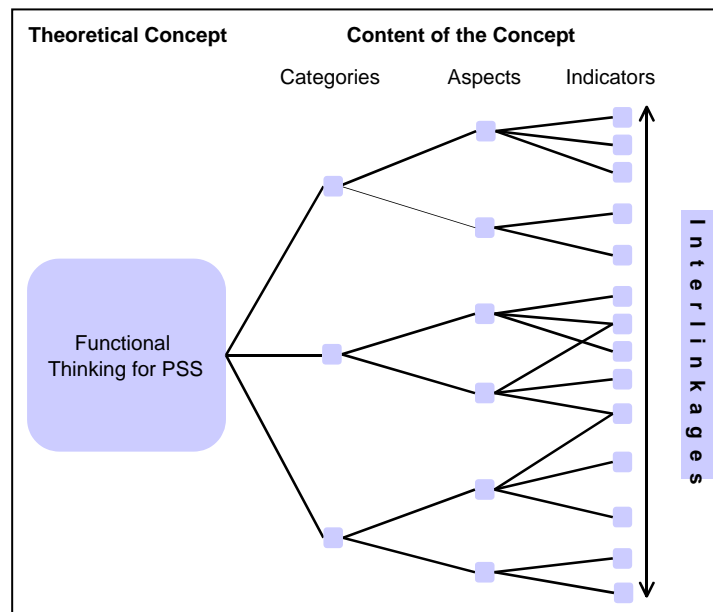


Figure 4 – Deriving categories and aspects of “functional thinking for PSS” through the method of concept specification.

The main deducted categories are found to be addressing three levels of organisational dynamics i.e. sole internal issues (corporate culture), internal issues in response to the business environment (organisational learning) and external issues (utilisation of resources for networking) (Figure 5).

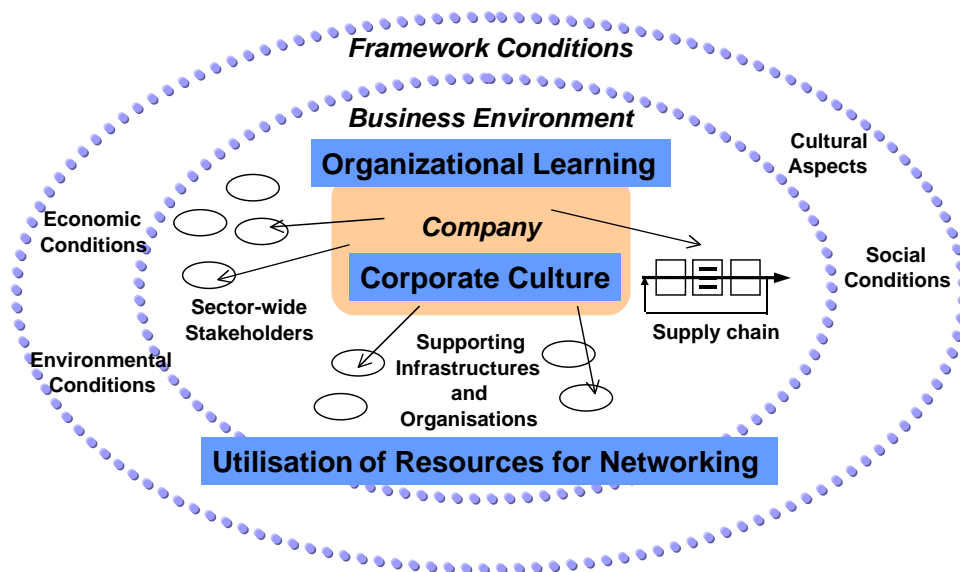


Figure 5 – Positioning the categories for business preparedness in the company, surrounding business environment and framework conditions.

Major categories and aspects regarding business preparedness for “functional thinking” are then given in the following matrix:

Categories	Aspects
Corporate Culture (Internal Issues)	Vision, policy and strategy Are the company policies in line with the idea of providing a function but not product per se at low levels of resource consumption?
	Values and beliefs Are the values and beliefs among the employees in line with the policies?
	Organisational structure Is the organisational structure flexible enough to allow functional designs?
Organisational learning (Organisational issues in response to the business environment)	Leadership Is the organisation lead with a strong corporate leadership having a clear vision on functional thinking?
	Institutional capacity Are the traditional business units i.e. design, marketing, finance, HRM, etc. equipped with tools, services and training to perform function oriented tasks?
	Knowledge Management Are there mechanisms to distribute knowledge on technology and stakeholders in the corporation?
Utilisation of resources for networking (External Issues)	Strategic alliances and partnerships Does the company have organisational capabilities and tools to set up alliances with relevant actors (e.g. organisations of end-of-current-life management, consultancies, media agencies) in order to decrease the resource consumption of the system?
	Stakeholder relationships Does the company continuously monitor and take part in agenda setting?

3.2 Consumer acceptance of PSS Applications

Concept specification has lead to four major categories of factors influencing consumer acceptance. Each category is then divided into factors that shall be analysed by business when evaluating the ideas of PSS applications. It is assumed that all of the four major factors have the same level of importance in affecting the willingness of consumer to be involved with the network of PSS application. However, the level of detail of the source of the analysis, i.e. the collected examples in the ICT sector, did not allow for relative judgement of the aspects among each other.

Major categories and aspects regarding consumer acceptance of PSS Applications are then given in the following matrix:

Categories	Aspects
Individual Issues	Needs Are biogenic, psychogenic and sociogenic needs satisfied?)
	Motivation Are motivational conflicts eliminated?
	Involvement Are there mental or physical barriers of involvement with the PSS application?
	Attitudes Can a positive attitude towards the PSS application be formed?
	Self-concept Is the consumers' own beliefs matched with the PSS application?
	Income Is purchasing power of consumer considered?
Social Issues	Cultural System Does the PSS application support the physical infrastructure, social structure and mental characteristics of a society?
	Communication System Do the media support the PSS application?
Economic Issues	Cost Structure Is the cost structure competitive with respect to other forms of obtaining the same function?
Environmental Issues	Concern for environment Are the environmental concerns of consumers in line with the strategy of PSS application?

4. Conclusions

This paper suggests that reaching the vision of sustainable production and consumption calls for a systems approach. Noticed as a potential concept to capture this vision, similarly PSS applications shall be designed in full consideration of system dynamics and consumer side implications. Though, this is not seen as one actors' task and involvement of a diverse range of stakeholders is needed to develop an understanding of these socially constructed systems, whose characteristics are determined by individual, social, cultural, economic and technological frames of the actors involved in the construction. Only by then, less resource intensive applications and in particularly ones with less CO₂ emissions can be established.

It is implied with the research done in the ICT sector that it is harder to establish closed loop systems, especially in this sector, as long as consumers have the tendency to rematerialise the function provided. This effect leads a downstream shift in the life cycle with respect to CO₂ emissions. In this respect, businesses shall not stay as mediums facilitating such tendencies and shall take on the responsibility of designing a less resource intensive ways of supply the function and the required infrastructure.

For business, illuminating the way towards achieving this task simultaneously requires establishment of organisational mechanisms for functional thinking or PSS and development of an in-depth understanding of the consumer's reactions to the system dynamics. However, these mechanisms that will guide business to take action in this direction are not well researched. This paper suggests an initial view on business preparedness to take on the responsibility for involving consumers in the design of less resource intensive product service systems. It is concluded that more research is essential to comprehend the organisational dynamics and aspects that would lead business to take on functional thinking and a life-cycle perspective with a consumer focus.

On the other hand, possible difficulty in this direction of research is the absence of concrete data or cases. It is still not known for example whether business preparedness for different provision of different functions would differ. In this regard, the question: "Would the aspects of corporate culture, organisational learning or the way company resource utilised differ in cases of provision of nutrition, housing or fun?" still remains unclear. Furthermore, exactly to what extent the resource intensity of PSS applications get affected in relation to business preparedness is another inquiry to be raised. All in all, research in these areas is needed to obtain a clear picture for the business case and responsibility allocation.

Similarly, there is very limited number of case studies done on the consumer side implications i.e. the possible changes in the material intensity through the decisions they take. This brings in the difficulty of deriving a cause and effect link between the consumer behaviour and these systems. In this regard, rather qualitative methods can be offered.

This paper does not focus on the social aspects associated with PSS applications, since there are no viewpoints presented in the literature and there are no tools to evaluate the possible implications of PSS on societal issues. However, there is still the issue whether PSS concept can contribute to the social aspect of sustainable production and consumption systems as well it contributes lessening the resource use i.e. environmental impacts.

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Appendix

Box 1 – Some examples of PSS applications in the ICT sector (Adapted from Mont, 2001, p. 30-33, Kuhndt et al., 2002).

Mobility Services

- *Volvo car Corporation* in Sweden integrated GSM telephone with built-in GPS unit for satellite navigation, linked directly to a Volvo “On Call Centre”, which provides a constant assistance to the driver. The ICT applications to support transport are commonly collected under the heading of “telematics”.
- *Tetra-Pak* uses video-conferencing by substituting business travel and personal meetings with videoconferences. Tetra-Pak minimised costs for travel with 15 million SEK, corresponding to approximately 10% of all company costs for travels ordered within Sweden.
- Telework applications. Using information technology and technology for data transmission, a considerable proportion of employee’s working time is organised away from the place of output delivery or a firm’s basis.

Product-based e-commerce

- *Matomera* is a web-based supermarket that provides a weekly menu and special menu. The company only owns a storage area eliminating the need for displays as in the traditional supermarkets.
- Companies such as *Books-on-Demand* and *Amazon* offer services for ordering and paying for books in Internet.
- Ordering and paying for tickets for public transport via Internet.

Information-based e-commerce

- *Comhem* is an Internet company, which provides movies and similar TV programmes for download directly to the TV sets. This kind of service requires set up of a set-top box.
- Online banking, music and news servers.

Renting or Leasing Services

- *Thorn* is a Swedish company providing ICT products such as TV and music sets, which are made available to the consumer via three different routes i.e. renting, financial schemes and immediate purchase.
- *Xerox Corporation* started as a photocopier manufacturer and already for several years has been turned into a document company, focusing on the whole commercial documentation process. Via the Asset Management Programme, the products are leased or sold under a multi-year contract, which guarantees customer satisfaction through functioning machines as a fixed priced per copy.

Communication Services

- *Telia* and *Deutsche Telekom* provide consumers with virtual answering machines.

Table 1 – Strategies collected in the ICT sector corresponding to one of the three types of PSS applications.

Type of PSS Applications	Strategies
Supply Chain Optimisation Level decreasing the Material Intensity (MI) of a service unit from cradle to grave.	Selection of low impact materials Reduction of materials along the life-cycle of the product Optimisation of supply chain techniques Efficient distribution system Optimise use phase Optimise eol system
Network-wide Optimisation Level increasing the Service Intensity (SI) of a certain amount of material flow.	Life extension via modular design Multi-functionality as product meets several needs Use intensity via collective use of one product
System Optimisation Level decreasing the material flow and increasing the service intensity.	Service substitution; substitution of services by less resource intense means Integrated systems; integration of products and services into a system to meet functional performance Production on demand; supply of pre-determined demand